



The implications of mandatory low-cost fuel provision

Master of Science in Economics

Masters Thesis

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NOVA SCHOOL OF BUSINESS AND ECONOMICS

Fall Semester 2015/2016

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Lisbon, 8 January 2016

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Abstract

This work studies fuel retail firms' strategic behavior in a two-dimensional product differentiation framework. Following the mandatory provision of "low-cost" fuel we consider that capacity constraints force firms to eliminate one of the previously offered qualities. Firms play a two-stage game choosing fuel qualities from three possibilities (low-cost, medium quality and high quality fuel) and then prices having exogenous opposite locations. In the highest level of consumers' heterogeneity, a subgame perfect Nash equilibrium exists in which firms both choose minimum quality differentiation. Consumers' are worse off if no differentiation occurs in medium and high qualities. The effect over prices from the mandatory "low-cost" fuel law is ambiguous.

Keywords: two-dimensional product differentiation; heterogeneous quality preferences; low-cost fuel; mandatory provision

1 Introduction

On April 17th of 2015 new legislation imposed gas stations to provide a no-additives fuels (“low-cost” or simple fuels) option to consumers in Portugal.¹ Independently of the brand simple fuels’ level of additives is that needed to meet minimum quality requirements defined by law.² These fuels are similar to those sold by large retail chains and unbranded operators. Over the past decade independent/unbranded gasoline stations selling exclusively low-cost fuels have been gaining market share to branded stations.³ Unbranded stations are usually operated by large grocery retailers and located next to their stores while branded stations often provide ancillary services such as car wash, tire-fill, loyalty cards, and products of convenience. Fuels can be categorized in three segments according to its quality: regular (simple or low-cost), medium and premium. Premium fuels are the top-quality fuels, with the highest concentrations of additives and the simple fuels are those with lower concentrations of additives. To justify this policy, the government argued that it would promote competition lowering prices for the consumer and more freedom of choice. Major branded fuel retailers’ stations criticized the measure, arguing that their business model involves other costs that would prevent them to keep up with unbranded stations prices for low-cost fuel.⁴ Another argument against the measure was the possible damage to the freedom of choice given that capacity constraints would dictate the elimination of other

¹ Law no. 6/2015: <http://goo.gl/UA4mJy>

² Decree law no. 142/2010, of 31 December

³ According to the Portuguese Competition Authority between 2008 and 2013 low-cost fuels market share grew from 12% to 25%. In 2015 a study by Kantar contracted by the Portuguese Association of Distribution Companies indicates that low-cost fuels account for more than 28% of the market.

⁴ Four oil companies operating in Portugal (Galp, Repsol, BP and Cepsa) offering branded fuels and freely deciding on their recommended and maximum prices. Please refer to OECD (2014) to a more detailed description of the market organization.

qualities in order to offer low quality fuel. Mandatory introduction of simple fuel and stations' capacity constraints forced firms to choose which of the qualities (standard or premium) should be replaced for the former. The choice of which quality to eliminate can be seen as a strategic one, from which a game between firms emerge. Firms decide by anticipating other firms' and consumers' behavior as well as prices and profits resulting from competitive interactions. Naturally, differences in quality, location, production costs and consumers' tastes influence the market dynamics. Profits will ultimately determine which products will be available in the market.

This paper is organized as follows. In section 2 a contextualization of this paper in the existing literature is made. Section 3 introduces a description of the different models used to analyzed competition under two-dimensional product differentiation. In Section 4 each model is developed. Equilibrium prices, demands and strategies' payoffs are found and main results are exposed.⁵ Finally, Section 5 presents concluding remarks.

2 Literature Review

Competition in fuel/gasoline retail market has been recurrently the core of many empirical studies over the last decades. Most literature focus on the study of two important phenomena: asymmetric Edgeworth price cycles and collusion behavior.⁶ Maskin and Tirole (1988) first formalized the Edgeworth cycle concept, describing it as an equilibrium where *"firms undercut each other successively until the price reaches the competitive level at which point some firm eventually reverts to the high price"*. Several works (e.g., Noel,

⁵ For the third model further analysis regarding equilibrium prices and welfare is performed.

⁶ Edgeworth (1925) argued that stationary price equilibrium doesn't take place when firms are confronted with capacity constraints. The concept was later formalized by Maskin and Tirole (1988)

2004; Verlinda, 2008; Noel, 2011) find proof that firms engage in Edgeworth cycles' behavior, leading to a fast price increase and a slower price decrease stages. Others focus on the speed of price adjustments to cost variations. Bacon (1991), Borenstein et al. (1992), Golby et al. (2000), Johnson (2002) used significant datasets to confirm asymmetries in price adjustments also known as "*rockets rise faster and feather fall slower*" events. Borenstein (1997) explains such asymmetry with the uncertainty of competitors' costs, but others such as Johnson (2002) explain it with the incentives for buyers to engage more intensively in searching prices. Relevant works also focused on tacit collusion between firms in retail fuel markets. Such behavior may be related to asymmetric price adjustments which provides strong reasons to study firms' strategic behavior.⁷ Supported by distinct theoretical models, important empirical works (Shepard and Borenstein, 1996; Wang, 2008; García, 2010) provide strong evidence of collusive behavior in different fuels retail markets.

Representing fuel market's organization and dynamics is not an easy task. Fuels can easily be considered to be differentiated over two dimensions: vertical and horizontal. While literature addressing one dimensional product differentiation is extensive, works accommodating the two dimensions are not as common. Hotelling (1929) made one of the first attempts to model horizontal differentiation, where firms compete in a two-stage location-price game.⁸ A significant number works followed further exploring Hotelling-type models. Either by considering a circular city, free entry and large number of firms as Salop, 1979) or key calculations' corrections and quadratic transportation costs

⁷ Clark and Houde (2011) identified evidence of asymmetric pricing cycles being an important feature associated with a price-fixing cartel.

⁸ First choosing locations (in a unitary "linear city") and then prices of homogeneous products.

(d'Aspremont et al. 1979) location models have been widely used. Concerning the vertical dimension Gabszwick and Thisse (1979, 1980) tried to “*capture an important fact of life: the quality component of the choice in economic decisions*” accommodating consumers’ with similar tastes but distinct income and firms with substitute products competing in the same market. Shaked and Sutton (1982) extended the exercise by considering a previous stage where two firms choose or not to enter the market and then to decide on maximal or minimal quality differentiation.⁹ Similarly to location models, in quality differentiation usual results show differentiation being a way to soften price competition and exploit consumers’ surplus. Some literature has developed competition models encompassing both vertical and horizontal dimensions. Economides (1989) analyses a sequential game of variety(location)-quality-price choices to find evidence of maximally differentiated varieties but minimal differentiation on the other dimensions. This result is consistent with that of Irmen (1988) –firms identify a dominant dimension to maximally differentiate in while minimum differentiation holds for all other dimensions.¹⁰ Other literature also provides interesting results in the two-dimensional framework but do not closely relate to the scope of this work.¹¹ Although with significant similarities in what concerns to models specification to my best knowledge none of the existing literature focuses on firms’ decisions about quality differentiation arising from both public intervention and capacity constraints – the core issue of the present document.

⁹ Results yielded both firms entering the market and producing differentiated products which would allow for price competition to be relaxed and positive firms for both firms.

¹⁰ Conceptualized by Hotelling (1929).

¹¹ Tabuchi (1994) focuses on the conditions necessary for equilibrium to occur when duopolistic firms are not allowed to take mixed strategies (in a two-dimensional two-stage game); and Degryse (1996) studies the interaction between vertical and horizontal differentiation in banking services.

3 The Models

All following models consider product differentiation occurring in horizontal and vertical dimensions. Horizontal dimension respects to the firm's location (y) while vertical differentiation refers to quality. With two products horizontal differentiation means that at the same price consumers do not agree on the preferable product. When vertical differentiation occurs all consumers agree on the most preferable product.¹² Each consumer is characterized by its location, usually also referred to as preference for variety (x , $x \in [0;1]$) and its preference for quality (θ , $\theta \in [\underline{\theta}; \bar{\theta}]$). Each product is characterized by its location and quality. For all cases studied it is assumed that firms cannot change from an exogenous location. We assume that firm 1 is has location $y = 0$ and firm 2 is located at $y = 1$.¹³

3.1. Homogeneous consumers and two qualities

In the first model firms cannot choose the quality of its fuels in a continuum of quality, as consumers perceive the market by 3 categories. Instead firms have to choose between offering the high quality fuel or the medium quality (as low-cost quality is mandatory by law and only two slots for quality offer exist in fuel stations).

In this duopoly firms simultaneously compete in qualities in the first stage and in prices in the second stage. Having capacity constraints regarding the number of positions it can assume in the vertical dimension, each firm faces a choice of quality to offer (whereas the

¹² When products have the same price and location.

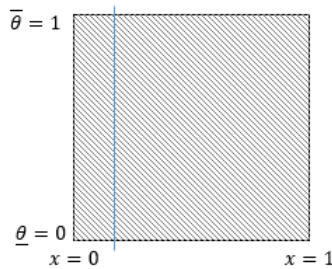
¹³ Relevant literature on horizontal differentiation suggests that firms tend to maximize horizontal differentiation: d'Aspremont et al. (1979), Netz and Taylor (2002), Economides (1985) and Neven (1985).

other quality must be excluded). That choice is made anticipating competitors' and consumers' behavior.

3.2. Heterogeneous consumers and two qualities

Consumers are uniformly distributed over a rectangular space of characteristics. Characteristics are each consumer's location (x) in the unit interval ($x \in [0; 1]$) and θ , θ representing the valuation of quality. While in the previous setting consumers were assumed to have equal tastes for quality ($\theta = 1$), here tastes vary across individuals. Such as in similar applications – Economides (1989) – we normalize θ without loss of generality so that $\theta \in [0; 1]$. Consumers are thus uniformly distributed over the unit square $Z = [0; 1] \times [0; 1]$. The product space is defined by the quality characteristic delimited by the qualities of the lower quality and higher quality fuels ($s, s \in [s^L, s^H]$). Firms' quality choices are not continuous as they can only choose between the lower (s^L) and higher quality fuels (s^H) being therefore restrained from choosing any level of quality in between.

Figure 1 - Consumers uniformly distribution over the characteristics space



This setting encompasses both 2-dimensions differentiation and varying tastes for quality. For each location x , consumers located in the same vertical line (see figure 1) have heterogeneous tastes, meaning that consumers are differently “attracted” by quality.

3.3. Heterogeneous non-continuous tastes and three qualities

Although firms' choice is between premium and regular fuels, the obligation to supply low-quality fuel certainly influences firm's decisions. Hence there is interest in examining a three-qualities market setting. An ideal exercise would accommodate continuous and heterogeneous preferences for quality in the existence of three qualities. The presence of an equilibrium would be analyzed as usual in order to assess the possible outcomes of the game. Such exercise entails a complex system of equation mainly as a consequence of non-linear demands, limiting the scope for useful results and implications.

The following model is, without loss of generality, a simplified alternative that considers a concentration of consumers along three different Hoteling lines, each corresponding to different levels of taste for quality θ^L , θ^M and θ^H (with $\theta^L < \theta^M < \theta^H$). Each line has length 1 and a mass of $1/3$ consumers uniformly distributed over it, ensuring that the total mass of consumers is 1, as in the previous exercises. Although the taste for quality is not continuous, this ensures a certain degree of heterogeneity in consumers' tastes for quality. The individual consumer utility is given by

$$v + \theta s_i - p - t(\text{distance}) \quad (1)$$

Fuels' quality levels are defined *a priori*, and assumed to be represented by $s^L = 0$, $s^M = \frac{1}{2}$ and $s^H = 1$. Marginal costs of production are quality specific across firms, respecting the relation $c^L < c^M < c^H$.

4 Strategies, Equilibria and Implications

In the following models we use backward induction to search for the existence of a subgame perfect equilibrium. Firms first compete in qualities and then prices. By performing the usual profit maximization exercise – after identifying consumers' indifference relations and demands for each product – equilibrium prices are obtained. Finally demands and profits resulting from equilibrium prices are found. For each model a table of payoffs displays firms' profits for each outcome. Analysis will focus on the existence or not of subgame perfect Nash equilibria in quality, on the different conditions for each equilibrium market configuration and on the conditions dictating asymmetric quality choices being or not an equilibrium.

4.1. Homogeneous consumers and two qualities

The indifferent consumer is located at x where its utility of buying from firm 1 is equal to that achieved by buying from firm 2, respecting:

$$v + s_1 - p_1 - t(x) = v + s_2 - p_2 - t(1 - x) \quad (2)$$

Hence the indifferent consumer is located at:

$$x = \frac{s_1 - s_2 + p_2 - p_1 + t}{2t} \quad (3)$$

Note that because x is increasing in s_1 and decreasing in s_2 it is clear that the higher firm's 1 quality is compared to 2's, the higher will be its market. Because all consumers located in the interval $[0; x(t)]$ derive more utility from purchasing from firm 1, (3) gives us the

demand for firm 1 ($1 - D_1 = D_2$). To ensure that a firm is never priced out of the market the following condition has to be respected

$$\frac{\Delta s_i - \Delta P_i}{3t} < 0,5 \quad (4)$$

From this point each firm can find its profit maximizing prices (or response function) (xxx) and, by incorporating the other firm's response function, equilibrium prices can be found, depending on the qualities, transportation costs and production costs of the different products (note that different qualities have different constant marginal costs of production. Firm i 's price at equilibrium will be:

$$p_i^* = \frac{s_i - s_j + 3t + 2c_i + c_j}{3} \quad (5)$$

With the second stage equilibrium prices firms' profits at equilibrium can be easily determined, as a function of all marginal costs, qualities and transportation costs – please see equation (8) further in this section. Regarding the choice of quality three situations can happen:

1. Both firms choose to offer the premium (high quality) fuel;
2. One firm decides to offer the premium (high quality) fuel while the other chooses to offer the regular (lower quality) fuel;
3. Both firms choose to offer the regular (low quality) fuel.

Note that in the cases 1 and 3, where both firms offer the same quality, this exercise boils to a standard Hotelling line situation – with differentiation happening only in the horizontal dimension. Being the qualities and consequently the costs, the same for both firms,

competition dictates equal split of demand and profits between firms and the indifferent consumer has its location in the middle of the unit segment. Equilibrium prices are then equal across firms corresponding to the Hotelling model, yielding:

$$p^* = p_1 = p_2 = t + c \quad (6)$$

However, when situation 2 occurs differentiation is both in quality and location. Being the qualities chosen different prices will also be distinct. The difference in the equilibrium prices is given by:

$$\frac{2\Delta s_i + \Delta c_i}{3} \quad (7)$$

with $\Delta s_i = s_i - s_j$ and $\Delta c_i = c_i - c_j$, $j, s = 1, 2, j \neq s$

Making the assumption $|\Delta s_i| > |\Delta c_i|$ it is an immediate result a higher price for the higher quality product and a lower price for the lower quality, when comparing to the prices that would emerge as an equilibrium in case of a market outcome of only one type of fuel being offered. Whatever the case, taking equilibrium prices and subsequent demand for those prices into consideration, profits in equilibrium are determined by:

$$\pi_i = \frac{t}{2} + \frac{\Delta s_i - \Delta c_i}{3} + \frac{\Delta s_i^2 - 2\Delta s_i \Delta c_i + \Delta c_i^2}{18t} \quad (8)$$

with $\Delta s_i = s_i - s_j$ and $\Delta c_i = c_i - c_j$, $j, s = 1, 2, j \neq s$

Note that, as indicated, situations 1 and 2 correspond symmetric demand and hence profits in equilibrium, being the former equal to

$$\pi_1 = \pi_2 = \frac{t}{2} \quad (9)$$

Table 1 - Payoffs (profits) by firm according to choice pairs (model 1)

Firms' choices		FIRM 2	
		Low Quality	High Quality
FIRM 1	Low Quality	$(\frac{t}{2}; \frac{t}{2})$	$(\frac{t}{2} + \Delta\pi_1^L; \frac{t}{2} + \Delta\pi_2^H)$
	High Quality	$(\frac{t}{2} + \Delta\pi_1^H; \frac{t}{2} + \Delta\pi_2^L)$	$(\frac{t}{2}; \frac{t}{2})$

Given one firm's quality, the other firm's profit difference between choosing the same or a different quality is given by the difference between (5) and (6):

$$\Delta\pi_i = \frac{\Delta s_i - \Delta c_i}{3} + \frac{(\Delta s_i - \Delta c_i)^2}{18t} \quad (10)$$

with $\Delta s_i = s_i - s_j$ and $\Delta c_i = c_i - c_j$, $j, s = 1, 2, j \neq s$

$\Delta\pi = \Delta\pi_i^H$ if firm i chooses to offer the higher quality and firm j the lower one

$\Delta\pi = \Delta\pi_i^L$ if firm i chooses to offer the lower quality and firm j the higher one

Table 1 provides information on the profits each firms obtains in the different outcomes. Note that from (10) it is clear that both $\Delta\pi_i^H$ and $\Delta\pi_i^L$ are always positive. A direct implication is that the pairs (low; high) and (high; low) are subgame perfect Nash equilibria in pure strategies for quality choices - no firm has an incentive to unilaterally move away from that outcome. If a firm chooses "low" than the other firm would prefer to choose "high", whereas if a firm chooses to play "high" than the other would find it more profitable to play "low". The pairs (low; low) and (high; high) are never subgame perfect Nash equilibria, as both firms have incentives to deviate from such outcomes.

Regarding the magnitude of the differences in profits from breaking from a (high; high) or (low; low) qualities equilibrium, the higher the difference in quality comparing to that of marginal costs – see equation (11) below – the bigger profits' difference is. If it comes to a point where between fuels of different qualities, the cost of producing a higher quality

exactly equals the increase in quality, then no benefits are created from the firm by changing the quality offered. The costs increase effect equals the quality increase effect leaving the profits unchanged.

$$\lim_{\Delta c_i \rightarrow \Delta s_i} \Delta \pi_i = 0 \quad (11)$$

4.2. Heterogeneous consumers and two qualities

The indifferent consumer is that in such location that the following equality occurs:

$$v + \theta s_1 - p_1 - t(x) = v + \theta s_2 - p_2 - t(1 - x) \quad (12)$$

Rewriting the expression, one obtains firm 1's market share for type θ :

$$x(\theta) = \frac{\theta(s_1 - s_2) + p_2 - p_1 + t}{2t} \quad (13)$$

Integrating (11) from 0 to 1 in θ the expression for firm 1's total demand is found:

$$\int_{\underline{\theta}}^{\bar{\theta}} x(\theta) = \int_0^1 x(\theta) = D_i = \frac{1}{2} + \frac{s_1 - s_2 + 2(p_j - p_i)}{4t} \quad (14)$$

From which the following condition is withdrawn to ensure that no firm is priced out of the market by the other firm:

$$\frac{s_1 - s_2 + 2(p_j - p_i)}{4t} < 0,5 \quad (15)$$

Employing the computed expressions for demand and performing the profits maximization in respect to own prices, profit-maximizing prices for each firm – response functions – are obtained allowing the calculation of prices in equilibrium:

$$p_i^* = t + \frac{2c_i + c_j}{3} + \frac{s_i - s_j}{6} \quad (16)$$

It immediately follows that whenever firms choose to offer the same quality, prices will be the same. If firms' choice leads to quality differentiation, then the high quality fuel will also have a higher price – the higher the cost and quality gaps between the two qualities the higher the price difference – comparing to the low quality one.

It is also interesting to analyze the effect of differentiation on the prices of the different products having as baseline the situation where the market offers only one quality. Whether the price of the high quality fuel offered by one firm (when the other firm offers the alternative quality) is higher or lower than the equilibrium price of that same quality when both firms offer it depends on the relations between cost and quality levels' difference. The same inference is valid for the case of the low quality fuel.

$$P_i^{H(H)} - P_i^{H(L)} = P_i^{L(H)} - P_i^{L(L)} = \frac{2(c^H - c^L)}{6} + \frac{(s^L - s^H)}{6} \quad (17)$$

Note that the last term of the equation is always negative, while the penultimate is always positive. The resulting impact arises from the difference relation of these terms. If $\frac{2(c^H - c^L)}{6} > \frac{(s^L - s^H)}{6}$ low cost product price is higher when firms differentiate and the high quality fuel's price is higher when both firms offer that quality. If $\frac{2(c^H - c^L)}{6} < \frac{(s^L - s^H)}{6}$ the opposite occurs. Incorporating equilibrium prices in the profits function, profits in equilibrium are derived and given by:

$$\pi_i = \frac{t}{2} + \frac{7\Delta s_i}{12} - \frac{\Delta c_i}{2} + \frac{\Delta s_i^2}{12t} + \frac{\Delta c_i^2}{9t} - \frac{4\Delta s_i \Delta c_i}{18t} \quad (18)$$

with $\Delta s_i = s_i - s_j$ and $\Delta c_i = c_i - c_j$, $j, s = 1, 2, j \neq s$

As in the previous model, when firms do not differentiate themselves in the quality dimension, their profits in equilibrium are the same regardless of the quality offered. The exercise comes down to a Hotelling outcome. To find a hypothetical equilibrium it is essential to look at the possible payoff pairs resulting from the game:

Table 2 - Payoffs (profits) by firm according to choice pairs (model 2)

Firms' choices		FIRM 2	
		Low Quality	High Quality
FIRM 1	Low Quality	$(\frac{t}{2}; \frac{t}{2})$	$(\frac{t}{2} + \Delta\pi_1^L; \frac{t}{2} + \Delta\pi_2^H)$
	High Quality	$(\frac{t}{2} + \Delta\pi_1^H; \frac{t}{2} + \Delta\pi_2^L)$	$(\frac{t}{2}; \frac{t}{2})$

Again, for simplicity of the analysis, considering the possibility of isolated modes from a first set of choices, $\Delta\pi_i$ represents the difference in profits one firm would face by moving from a situation where they offer the same quality, assuming that the other firm does not change its own quality.

$$\Delta\pi_i = + \frac{7\Delta s_i - 6\Delta c_i}{12} + \frac{3\Delta s_i^2 + 4\Delta c_i^2 - 8\Delta s_i\Delta c_i}{36t} \quad (19)$$

with $\Delta s_i = s_i - s_j$ and $\Delta c_i = c_i - c_j$, $j, s = 1, 2, j \neq s$

$\Delta\pi = \Delta\pi_i^H$ if firm i chooses to offer the higher quality and firm j the lower one

$\Delta\pi = \Delta\pi_i^L$ if firm i chooses to offer the lower quality and firm j the higher one

From (19) it immediately follows that while $\Delta\pi_i^H$ can be either positive or negative, $\Delta\pi_i^L$ is always negative. There are thus two variations: when $\Delta\pi_i^H$ is positive and $\Delta\pi_i^L$ negative; when $\Delta\pi_i^H$ is negative and $\Delta\pi_i^L$ also negative. In the first case firms have an equilibrium in dominant strategies choosing to play “high” – leading to the outcome (high; high). That outcome is a subgame perfect Nash equilibrium in weakly dominant strategies, as any move

yields lower profits for the firm changing strategy and even allows the competitor to increase profits without having to change its strategy. When both elements are negative, situation to which, *ceteris paribus*, eventual increases in the transportation costs parameter t contribute, then firms have a symmetric Nash equilibria in pure strategies in choosing not to differentiate in qualities – that is, both playing “high” or both playing “low”. Whatever the case, subgame perfect Nash equilibria is only present in scenarios where no vertical differentiation occurs. It is also interesting to note that the more “sensitive” consumers are to the horizontal dimension the more likely are firms not to differentiate in the vertical dimension.

$$\lim_{\Delta c_i \rightarrow \Delta s_i} \Delta \pi_i = \frac{3\Delta s_i}{36} - \frac{\Delta s_i^2}{36t} \xrightarrow{\text{yields}} \begin{cases} \Delta \pi_i > 0, \text{ for } \Delta s_i \in [0; 1] \\ \Delta \pi_i < 0, \text{ for } \Delta s_i \in [-1; 0] \end{cases} \quad (20)$$

Computations in (20) also present useful aspects. For a situation where both $|\Delta s_i|$ and $|\Delta c_i| \in [0; 1]$, $\Delta \pi_i$ is always positive when a firm offers the high quality fuel whereas the opposite occurs when the low quality fuel is the firm’s choice.¹⁴ In this setting outcome (high; high) is a subgame perfect Nash equilibrium in dominant strategies.¹⁵

4.3. Heterogeneous non-continuous tastes and three qualities

Initial analysis focuses on the situation where both firms offer the low-quality fuel, and then differentiate themselves in the remaining qualities (firm 1 offers the high-quality fuel and firm 2 offers the medium-quality fuel – this specific choice is irrelevant due to the symmetry of results in an opposite case). In order to perform the profits maximization that

¹⁴ Consider the normalization $t = 1$.

¹⁵ Note that $\Delta \pi_i < 0$, for $\Delta s_i \in [-1; 0]$, that is, firms have no incentive to switch its offer from the high quality fuel to the lower quality one, as it decreases own overall profits.

allow for the search of equilibrium prices, demands are obtained from the indifference relations present in this framework. It is assumed that consumers consume the quality “closer” to their tastes, meaning that whenever the market offers all qualities, consumers with lower taste for quality (θ^l) will only choose between low and medium qualities while consumers with higher taste for quality (θ^h) would choose only between high and medium qualities.

Indifference relations:

- For θ^h consumers, between high and medium quality fuels (21);
- For θ^m consumers, between high and medium quality fuels (22); and between medium quality and low quality (supplied by firm 1) fuels (23)
- For θ^l consumers, between medium quality and low quality (supplied by firm 1) fuels (24); and between low quality fuels supplied by the two firms (25)

$$x = \frac{p_2^M - p_1^H}{2t} + \frac{1}{2} + \frac{\theta^h}{4t} \quad (21)$$

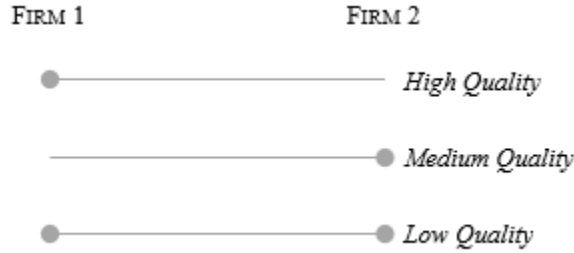
$$x = \frac{p_2^M - p_1^H}{2t} + \frac{1}{2} + \frac{\theta^m}{4t} \quad (22)$$

$$x = \frac{p_2^M - p_1^L}{2t} + \frac{1}{2} - \frac{\theta^m}{4t} \quad (23)$$

$$x = \frac{p_2^M - p_1^L}{2t} + \frac{1}{2} - \frac{\theta^l}{4t} \quad (24)$$

$$x = \frac{p_2^L - p_1^L}{2t} + \frac{1}{2} \quad (25)$$

Figure 2 – Firms’ and Consumers’ space of characteristics illustration



Observing figure 2 the location of each of the indifferent consumers’ position entails relevant underlying assumptions. If, as depicted, $(25) < (24)$ and $(22) < (23)$ this is equivalent to $p_2^M - p_1^L > \frac{\theta^l}{2}$ and $p_1^H - p_1^L > \theta^m$. This means that no θ^m consumer prefers

the high quality fuel over the low-quality fuel provided by firm 1; and no θ^l consumer prefers the medium quality fuel over the low quality fuel supplied by firm 2, as the increase in utility is not enough to compensate the higher price. In an opposite case, that is $p_2^M - p_1^L < \frac{\theta^l}{2}$ and $p_1^H - p_1^L < \theta^m$ there would be no demand for firm 1's low quality fuel.

Hence, aggregated demands for each product yield:

$$D_1^H = \frac{1}{6} + \frac{p_2^M - p_1^L}{2t} \frac{\theta^h}{4t} \quad (26)$$

$$D_1^L = \frac{2}{6} + \frac{p_2^M + p_1^L - 2p_1^L}{2t} \frac{\theta^h}{4t} \quad (27)$$

$$D_2^M = \frac{2}{6} + \frac{p_1^H - p_1^L - 2p_2^M}{2t} + \frac{\theta^m - \theta^h}{4t} \quad (28)$$

$$D_2^L = \frac{1}{6} + \frac{p_1^L - p_2^L}{2t} \quad (29)$$

With demands, profits – at an aggregated level for each firm, that is, considering for each firm the costs, prices and demand associated with each specific product they offer – can be easily computed, allowing for the profit maximization exercise, in order to find equilibrium prices. Equilibrium prices found lead to specific demands (at equilibrium) and consequently profits. To test this market setting – where firms differentiate themselves in the quality-choice available, given that both are required to offer the low quality fuel, these profits have to be compared to those arising from the other possible market configurations: both firms offering the low-quality and the medium quality fuels; or both firms offering the low quality and high quality fuels. In both these cases the exercise is simplified to a classical Hotelling. Regardless the assumptions – regarding consumers' preferring always one quality to another – in equilibrium firms will equally divide the market and earn profits:

$$\pi_i = \frac{3t}{18} \quad (30)$$

Firms, by anticipating the possible outcomes of the game, will ultimately choose the strategy that leads to higher payoffs (profits). The following table shows the profits emerging for each of the firms according to the possible strategies. Although not specifically identified these are the aggregate profits – that is, also considering those arising from supplying the low-quality fuel – as the setting

Table 3 - Payoffs (profits) by firm according to choice pairs (model 3)

Firms' choices		FIRM 2	
		Medium Quality	High Quality
FIRM 1	Medium Quality	$\left(\frac{3t}{18}; \frac{3t}{18}\right)$	$\left(\frac{3t}{18} + \Delta\pi_1^M; \frac{3t}{18} + \Delta\pi_2^H\right)$
	High Quality	$\left(\frac{3t}{18} + \Delta\pi_1^H; \frac{3t}{18} + \Delta\pi_2^M\right)$	$\left(\frac{3t}{18}; \frac{3t}{18}\right)$

$\Delta\pi_i^H$: if firm i chooses to offer the higher quality and firm j the medium one

$\Delta\pi_i^M$: if firm i chooses to offer the medium quality and firm j the higher one

Again, $\Delta\pi_i$ represents the difference in the total profits one firm would face by moving from a situation where the two firms offer the same quality, assuming that the other does not change its own quality. Please see elements $\Delta\pi_i^H$ and $\Delta\pi_i^M$ in appendix (A.12) and (A.13) respectively. Strategies are choosing either medium or high quality. Assessing possible equilibria depends not only on the differences of costs and qualities but also on the transportation costs (t). If both $\Delta\pi_i^H$ and $\Delta\pi_i^L$ are negative, then pairs (high; high) and (low; low) are symmetric Nash equilibria in pure strategies – any deviation $\Delta\pi_i$ would decrease the deviant's profits therefore firms will choose to minimal quality differentiation. By contrast, if $\Delta\pi_i^H$ and $\Delta\pi_i^L$ are both positive then the pairs (high; low) and (low; high) are asymmetric subgame perfect Nash equilibria in pure strategies. In a different situation, where one deviation can yield higher profits and a deviation on the opposite direction yields

lower profits then firms will both – see the symmetric properties (32) – have a weekly dominant strategy in choosing to offer the quality to which a deviation from a same-qualities pair results in higher profits. The resulting outcome will be the pair of same strategies (resulting in minimal vertical differentiation) from which no firm will have incentives to unilaterally move away from and therefore, a subgame perfect Nash equilibrium in dominant strategies.

These results, although limited in terms of interpretation, shed a light on how empty can policymakers' arguments be when firms-level information is opaque or not available to the public and governments. Further exploring the possibilities of this model one can look at the welfare implications of mandatory low quality fuel provision. Since fully covered market is being assumed one can search for the welfare distribution for the agents in the market. That assumption is maintained for consistency's sake. Although recognized that a welfare analysis under different conditions could also provide interesting results, it should follow configurations that account for non-fully covered markets. Given that all consumers buy fuel (whatever the quality or provider) prices provide all information about their welfare in market configurations where firms offer the same qualities. In a situation where only medium and high quality are offered consumers would pay a total of $t + \frac{2c^M + c^H}{3}$. Comparing with the cases where: both firms offer the low-cost and medium qualities; and that where both firms offer medium and low quality; a market situation where no low-cost is offered and both firms supply the remaining qualities yields lower aggregate consumers' expenditure. This suggests that consumers are worse off with this policy. In the alternative

situation where firms decide to differentiate themselves direction of the effect on consumers' expenditure cannot be identified beforehand. It depends on the magnitude of the differences between costs and also on the differences between the tastes for quality of heterogeneous consumers. In the scope of this model without clear information about the preferences' and costs' parameters policymakers would not have the ability to anticipate consumers' welfare variation.

5 Conclusion

This work aimed at exploring the challenges faced by fuel retailer firms as a result of legislation imposing mandatory supply of low quality fuel, and understanding the market implications of such measure. It has particularly focused on firms' strategic behavior under capacity constraints and two-dimensional product differentiation.

Results suggest that under no consumers' heterogeneity firms have two asymmetric Nash equilibria in choosing to differentiate over the quality dimension, both earning positive and higher profits than comparing with the no-differentiation alternative. However, when consumer heterogeneity is maximal (and continuous), vertical differentiation is not a subgame perfect Nash equilibrium. Instead, either in pure strategies or weakly dominating strategies, firms have a subgame perfect Nash equilibrium in opting for minimum quality differentiation. When no equilibria exist in pure strategies exists firms have a weakly dominating equilibrium in choosing to offer only high quality fuel. When considering a three-qualities setting firms' preferable strategies can not be identified *a priori*. Consistent across all models is the clear role the differences in quality between products play on the

magnitude of the incentives firms may have to differentiate. Differentiation can lead to both qualities being available at either higher or lower prices. Introduction of mandatory “low cost” fuels does not guarantee *per se* higher welfare to consumers. In fact, consumers can be jeopardized with such measure. If both firms offer exactly the same qualities consumers’ expenditure is higher than that verified when both firms offer medium and high qualities simultaneously. If firms choose to differentiate over the non-mandatory qualities the effect of consumers’ welfare is not clear, depending on the costs hiatus and level of consumer heterogeneity. After being required to offer “low-cost” fuel Portuguese retail firms chose a certain level of vertical differentiation as no quality was eliminated from the market.¹⁶ Under duopoly and assumed maximal differentiation on the horizontal dimension there is no evidence supporting with certainty (without knowing firms’ costs and consumers’ preferences and perceptions) the maximal differentiation on both dimensions is a stable equilibrium, but neither is evidence excluding the possibility.

This is merely a theoretical approach but the novelty of the policy studied demands further study. Empirical works could be developed with more transparent data allowing authors to test the robustness of theoretical models.¹⁷ Even without such data there is room for extending this work into considering settings comprising more firms in the market, search costs for consumers’, heterogeneous perceptions of quality and the ties between retail and higher levels on the vertical value chain of the fuels’ market.

¹⁶ Repsol, Cepsa and BP eliminated the medium quality fuel while Galp eliminated the premium quality fuel.

¹⁷ Law no. 6/2015 (<http://goo.gl/UA4mJy>) stipulates that a report on the implications of the mandatory low quality fuel provision should be studies summarized and publically presented.

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Appendix

A.1 Model 1

$$D_i(p_i^*, p_j^*) = \frac{1}{2} + \frac{\Delta s_i - \Delta c_i}{6t} \quad (\text{A-1}); \quad \pi_i = \frac{t}{2} + \frac{\Delta s_i - \Delta c_i}{3} + \frac{\Delta s_i^2 - 2\Delta s_i \Delta c_i + \Delta c_i^2}{18t} \quad (\text{A-2})$$

A.2 Model 3

If, besides the low cost fuel a firm decides to offer medium quality and the other firm high quality

$$p_i^H = \frac{t}{3} + \frac{5c^L + 14c^M + 26c^H}{45} + \frac{5\theta^m + 19\theta^h}{90} \quad (\text{A-4}); \quad D_i^H \frac{1}{6} + \frac{5c^L + 14c^M - 19c^H}{90t} + \frac{5\theta^m + 19\theta^h}{180t} \quad (\text{A-8})$$

$$p_j^M = \frac{t}{3} + \frac{10c^L + 28c^M + 7c^H}{45} + \frac{10\theta^m - 7\theta^h}{90} \quad (\text{A-5}); \quad D_j^M = \frac{1}{3} + \frac{20c^L - 34c^M + 14c^H}{90t} + \frac{20\theta^m - 13\theta^h}{180t} \quad (\text{A-9})$$

$$p_i^L = \frac{t}{3} + \frac{2c^H + 8c^M + 35c^L}{45} - \frac{10\theta^m + \theta^h}{90} \quad (\text{A-6}); \quad D_i^L = \frac{1}{3} + \frac{4c^H + 57c^M - 20c^L}{90t} - \frac{40\theta^m + 11\theta^h}{360t} \quad (\text{A-10})$$

$$p_j^L = \frac{t}{3} + \frac{c^H + 4c^M + 40c^L}{45} - \frac{10\theta^m + \theta^h}{180} \quad (\text{A-7}); \quad D_j^L \frac{1}{6} + \frac{c^H + 4c^M - 5c^L}{90t} \quad (\text{A-11})$$

$$\Delta\pi_i^H = (\pi_1^L + \pi_1^H) - \frac{3}{18}t \quad (\text{A-12}) \quad \Delta\pi_i^M = (\pi_2^L + \pi_2^M) - \frac{3}{18}t \quad (\text{A-13})$$

$$\Delta\pi_i^H - \Delta\pi_i^M = (\pi_1^L - \pi_2^L) + (\pi_1^H - \pi_2^M) \quad (\text{A-14})$$

$$\pi_1^L = \left[\left(\frac{t}{3} + \frac{2c^H + 8c^M - 10c^L}{45} - \frac{10\theta^m + \theta^h}{90} \right) \left(\frac{1}{3} + \frac{4c^H + 57c^M - 20c^L}{90t} - \frac{40\theta^m + 11\theta^h}{360t} \right) \right] \quad (\text{A-15})$$

$$\pi_1^H = \left[\left(\frac{t}{3} + \frac{5c^L + 14c^M - 19c^H}{45} + \frac{5\theta^m + 19\theta^h}{90} \right) \left(\frac{1}{6} + \frac{5c^L + 14c^M - 19c^H}{90t} + \frac{5\theta^m + 19\theta^h}{180t} \right) \right] \quad (\text{A-16})$$

$$\pi_2^L = \left[\left(\frac{t}{3} + \frac{c^H + 4c^M - 5c^L}{45} - \frac{10\theta^m + \theta^h}{180} \right) \left(\frac{1}{6} + \frac{c^H + 4c^M - 5c^L}{90t} \right) \right] \quad (\text{A-17})$$

$$\pi_2^M = \left[\left(\frac{t}{3} + \frac{10c^L - 17c^M + 7c^H}{45} + \frac{10\theta^m - 7\theta^h}{90} \right) \left(\frac{1}{3} + \frac{20c^L - 34c^M + 14c^H}{90t} + \frac{20\theta^m - 13\theta^h}{180t} \right) \right] \quad (\text{A-18})$$